Spatial ICT Clusters in Sweden – An Empirical Method to Identify a Necessary Condition for Existence

by

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Abstract:
An empirical method to identify the existence of a spatial cluster is proposed. The method, based upon regression analysis, offers researchers to categorise regions, municipalities, or cities with respect to their over- or under-representation in number of establishments and employment for any arbitrary industry. It is suggested that a necessary condition for the existence of a cluster entails a significant overrepresentation in both the number of establishments as well as in employment for any given sector in a region. Furthermore, this over-representation should be related to the size of the region. The categorisation generated by the proposed method has evident policy implications for any region aiming at developing and supporting a potential or emerging cluster. The present paper offers an analysis of the ICT-sector in Sweden, where the proposed method is used to identify potential clusters in the 81 Swedish functional regions. A comparison in time between 1990 and 2000 is also offered.

Key words: industrial clusters, agglomeration, economies of scale, ICT sector, functional region, Sweden,

1. Introduction

The information and communication technologies sector in Sweden (the ICT sector)[1] has experienced an unprecedented growth during the period 1990-2000. While employment in the private sector as a whole declined by 9 percent during the actual period due to a severe economic crisis Swedish employment in the ICT sector increased by 34 percent during the same period. However, the employment growth in the ICT sector has not been evenly distributed among the various regions in Sweden. A basic observation is that economic activities are clustered in space and the ICT sector is no exception.

The literature contains numerous definitions of the concept of a cluster. Any study of an economic phenomenon must start with some attempt to define the phenomena to be studied. Gordon and McCann (2000) argue that there are three analytically distinct forms of industrial clustering, each having its distinct logic. The three forms are

- The pure agglomeration model, referring to job-match opportunities and service economies of scale and scope
- The industrial complex model, referring to explicit links of sales and purchases between firms
- The network or club model, also referred to as the social network model.

However, irrespective of what cluster theoretic framework used to explain industrial clustering, there is first of all a need to find empirical tools that can be used to identify the existence of clusters. This is in particular important in a time when the cluster concept has become very popular in policy-making and people seem able to find clusters everywhere. For a cluster to exist in a region, we claim that the region in question must be characterised by a significant over-representation of cluster industry activities in terms of employment and firms. This means that there is a strong need to develop practical methods that are able to identify when the necessary conditions for the existence of a cluster in a region is fulfilled. Hence, in this study we use the concept of an industrial cluster in a very general way covering all the three forms identified by Gordon and McCann. Having established the existence of an industrial cluster the next step in the analysis is to identify which of the three forms the cluster belongs.

Given the potential agglomerative advantages that follow with industrial clustering one should expect regions having established clusters at the beginning of growth periods to have distinct advantages in the growth process and, thus, being able to generate more than their proportional part of growth activities. However, distinct growth periods also open up for the possibility for other regions to develop new clusters in growing industries. At the same time we also have to acknowledge the possibility that established clusters in some regions may decline even in growth periods due to a variety of reasons. For example, there might be a major shift in technology making it difficult for certain clusters to compete due to difficulties to adopt and adapt new technology within existing firms. Hence, it is important to understand the life cycles of industrial clusters.

[1] The industries defined as belonging to the ICT sector can be found in Appendix A.

In this paper we suggest a straightforward empirical method to identify industrial clusters and the proposed method is applied on the ICT sector in functional regions in Sweden for the years 1990 and 2000. This makes it possible to explore which regions that have ICT clusters in both years, which regions that had an ICT cluster in 1990 but had lost it by 2000, and which regions that have developed an ICT cluster during the 1990's. Furthermore, we examine the characteristics of the cluster regions in various respects trying to find common characteristics. We also study to what extent the economic development in the cluster regions has been different to that of the non-cluster regions.

The outline of the paper is as follows: Section 2 provides an introduction to the theory of industrial clusters with special emphasis on the dynamics of industrial clusters, i.e. on the life cycles of industrial clusters. In Section 3 an empirical method to identify the existence of industrial clusters is presented. The categorisation and analysis of the 81 Swedish functional regions is carried out in Section 4 and a summary alongside suggestions for further research is offered in Section 5.

2. The dynamics of industrial clusters

A basic observation is that economic activities are clustered in space (Marshall, 1920; Schumpeter, 1934; Dahmen, 1950; Perroux, 1955). According to Krugman (1991) the geographic concentration of production is evidence for the pervasive influence of some kind of increasing returns. When many firms in one sector cluster together, an industrial or sectoral cluster is said to exist. Inside such a cluster one or several forms of direct and/or indirect interaction is assumed to take place. This interaction generates positive externalities for firms belonging to the cluster. In McCann (2001) industrial clustering is described as place-specific increasing returns to scale, due to positive externalities that co-located activities generate. These economies also act as an attractor for localisation of other firms. Economic activities that are clustered together in space (in particular inside an urban region) are also termed agglomerations.

A recent article by Gordon and McCann (2000) provides a comprehensive assessment of various theoretical frameworks in which economic clusters have been discussed and researched. They find a tendency to use terms such as agglomeration, clusters, industrial districts, economic milieu and industrial complex more or less interchangeably, and with little concern of how to make these ideas operational. They suggest that the literature contains three basic notions of clustering: (i) the classic model of pure agglomeration, (ii) the industrial-complex model, and (iii) the network or club model focusing on social ties and trust. Here, for the subsequent discussion, only the two first notions are considered. In the pure agglomeration model externalities arise via the local market and local spillovers. The industrial-complex model stress the role of trading links and reduced transaction cost. The two notions merge in the sense that local markets and local transaction links can exist side by side in a functional region.

One of the first to emphasise the positive effects of co-location of firms was Marshall (1920). At least, Marshall was a pioneer in terms of analysing increasing returns in a more sophisticated framework. He recognised the interaction between internal and external economies of scale, as well as the cumulative relationship between internal economies of scale and size of the market outlets. In this process firms are drawn to regions with large market outlets, and the market outlets will be large because the firms are drawn to the market. This cumulative relationship is driven by internal economies of scale, demand and geographical transaction costs. Moreover, internal economies of scale of input suppliers give rise to external economies of scale for firms buying these inputs. This type of externality is canalised via the market, and is known as agglomeration effects. They create economies of scale for the whole economic milieu in the region.

According to Marshall's theoretical scheme, illustrated in Figure 2.1, there are three sources for the positive effects from clusters or agglomerations, namely (i) non-traded local inputs, (ii) local skilled-labour supply, and (iii) information spillovers. The first category may be considered as distance-sensitive inputs. Due to high geographic transaction costs these inputs are more expensive when delivered from sources outside the region. This implies that proximity becomes an advantage when firms are co-located. The second category of agglomeration economies is related to a firm's labour acquisition costs. In a region where a large share of the labour force already has specialised skills, the costs for a firm to expand its labour force may be lower than otherwise. For example, search and retraining costs can be assumed to be lower when the labour pool is large.

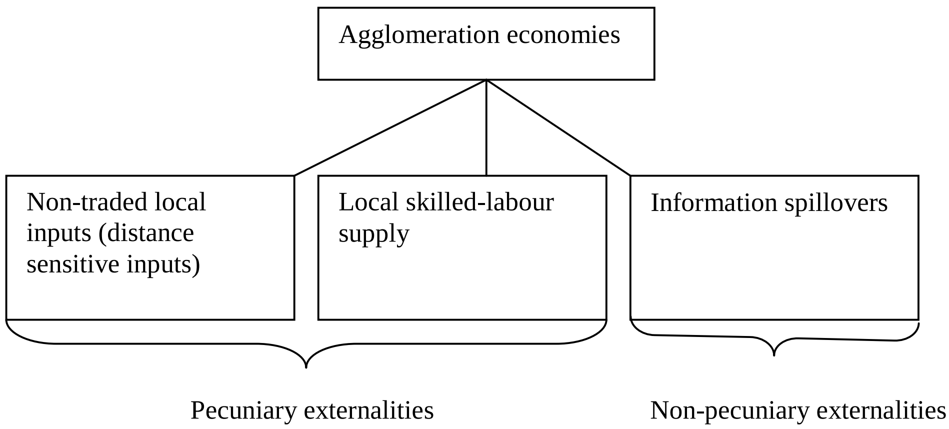

Figure 2.1 Causes of agglomeration economies in the Marshallian framework

The proximity to specialised input suppliers and specialised labour supply imply that inputs can be bought at a reduced price for specific quality levels. Because of this, the described phenomena are called pecuniary externalities. On the other hand, information spillovers have a non-pecuniary character. In some sense the information available in agglomerations is locally available as a public good, and brings benefits that are not charged any price, except in the form of land prices. The Marshall description is important from a theoretical point of view since it provides an explanation of the sources of agglomeration economies within an individual industry, i.e. in a single-industry cluster.

Another scheme for analysing agglomeration economies was outlined by Ohlin (1933). In contrast to Marshall, Ohlin focused more on how the individual firm is affected by co-location. In his classification there are four origins to agglomeration economies, as illustrated in Figure 2.2 below.

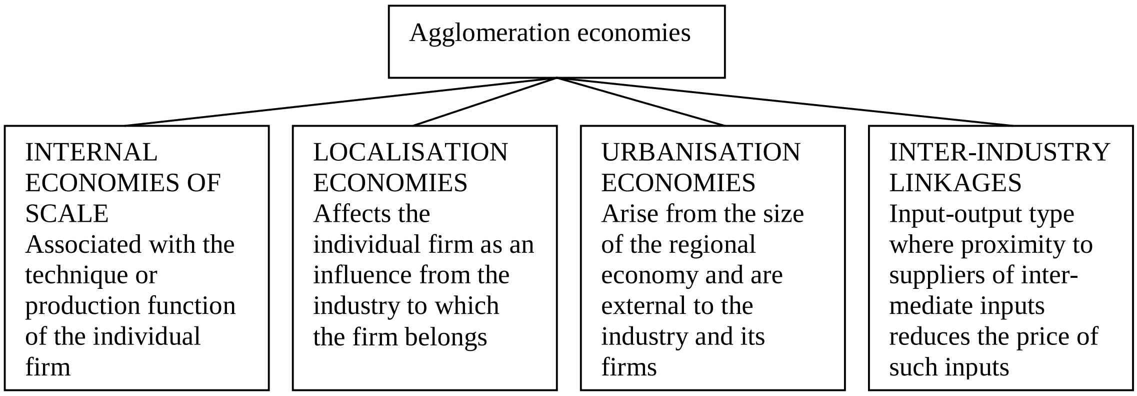

Figure 2.2 Causes of agglomeration economies in the Ohlin framework

Yet another famous classification of agglomeration economies was provided by Hoover (1937; 1948). In Hoover's setting, internal returns to scale are firm specific, localisation economies are industry specific and urbanisation economies are specific for each urban region. Hoover's approach is illustrated in Figure 2.3. This approach is important from a theoretical point of view since it makes it possible to identify the particular firms and industries which experience the different types of agglomeration economies.

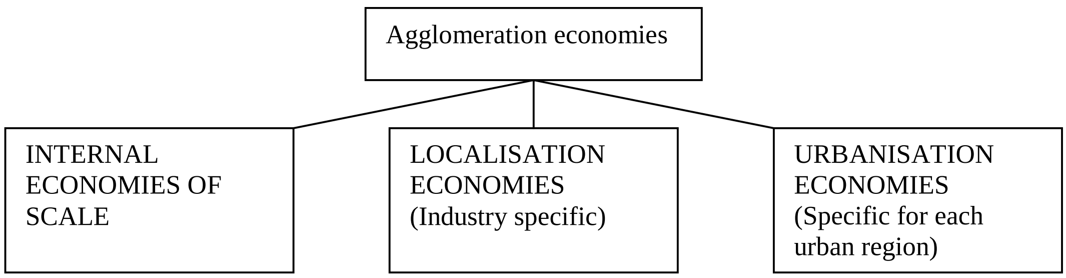

Figure 2.3 Causes of agglomeration economies in the Hoover framework

A fundamental feature common to all three approaches is proximity. Proximity to input suppliers and to customers are important aspects of agglomeration economies. It should be noted that proximity in these two respects can be substituted by links between suppliers and customers, formed in order to reduce transaction costs and hence to eliminate the influence of distance. Such links can develop into networks that have similar properties as clusters, even though the networks extend across regional boundaries. Proximity does not exclude that local networks are formed. However, proximity implies that it is easier to establish links for transactions and cooperation, and hence, it is also easier to rearrange such links more frequently.

The question concerning the emergence of agglomeration economies, i.e. clusters, was in the early 1990's raised by Paul Krugman. In Krugman (1991) the emergence of agglomeration economies is the result of an interaction between economies of scale that generates increasing returns, transportation costs, and regional market potential. What particularly distinguishes

Krugman's approach from former scholars is that Krugman's approach is dynamic in the sense that co-location of firms increases the regional market potential that stimulates location of more firms, and so on. What Krugman does is that he highlights the mechanisms behind the creation of industrial clusters. For him spatial agglomeration – geographical clusters – is the result of spatial lock-in. If, whether by historical accident, coordinated expectations or political decisions, one region becomes specialised in one particular type of industrial activity, then increasing returns to scale implies that producers within this particular activity find it especially advantageous to cluster there, and will continue to do so for an extended time period even as the economic and technological landscape changes about them (Quah, 2001). As described here, an industrial cluster can be in just a single industry. It does not need to be an entire spectrum of inter-related activities. It is really a main point in the Krugman framework that spatial clustering and agglomeration can arise even absent from inter-industry linkages.

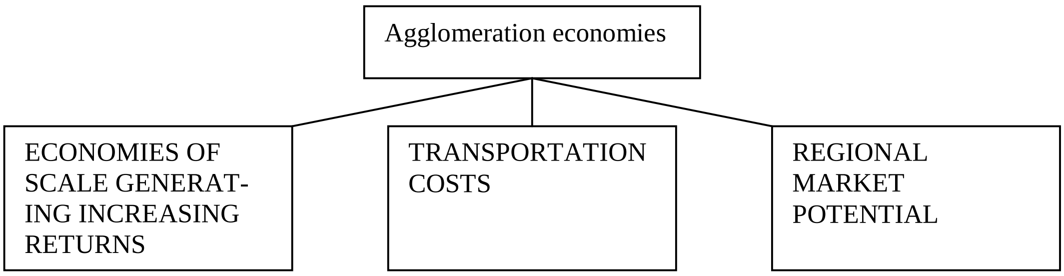

Figure 2.4 Causes of agglomeration economies in the Krugman framework

Overall the emergence of an industrial cluster in a functional region can be explained by that the region offers the industry or sector in question certain location advantages. Location advantages normally change slowly but they are developing over time and their evolution is path dependent. The observation that location advantages are dynamic brings two messages. First, one has to recognize that the development of a region's enduring attributes can have the form of a self-organised, cumulative and path-dependent change process. The second message is that location advantages can be created on the basis of conscious decision making by private and public policy makers, and this means that development has the form of an endogenous growth process, in which policy can play a meaningful role (Johansson, Karlsson & Stough, 2001, Eds.). One should however add, that in the same way as these forces may generate positive spirals they may under somewhat different circumstances generate negative spirals with deteriorating location advantages.

Capital formation in a region is a fundamental source of regional dynamics, where capital includes physical, financial, human and social capital. Not least, do the latter two influences the dynamics of location advantages in different regions. Universities and university colleges are typical agents of human capital formation, while various non-profit organisations and similar institutions are assumed to participate in the development of social capital. The latter can provide an arena for business, corporations, networks and the like to be self-organising. A focus on capital is a focus on created resources – and on the capacity to improve the resource supply in a temporal perspective. In this way the concept of dynamic location advantages is introduced and in this way we may understand the dynamics of industrial clusters.

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A particular aspect of the dynamics of industrial clusters is entry and exit processes, referring to firms and industries, to labour and knowledge/skill resources, and to financial capital. A related phenomenon is voice processes in regions, in particular when larger firms start to shed labour, shut down or move production away from the region. These processes play a central role for the emergence as well as the dissolution of industrial clusters in functional regions. In the processes the following phenomena is of particular importance:

a. Technology development inside firms, including education and retraining of the labour force, R&D and other forms or product and process development.
b. Technology development as an externally generated process, comprising diffusion in the form of knowledge spillovers and start-up incentives as well as inward direct investments.
c. Attraction of households embodying skills, experiences and knowledge. An important part of this dynamics is a region's capability to retain individuals who get their university education in the region.
d. Regional specialisation as a self-reinforcing process that generates external scale and scope economies including greater diversity of economic activities in growing clusters (and the opposite in declining clusters).
e. Cumulative change based on the interdependence between interaction-intensive transactions and various forms of scale economies, where economic expansion brings about growth of regional population and demand. Cumulative development of this kind may require a complementary development as regards infrastructure formation and land-use planning.

Scale economies are vital when we want to explain the existence of geographical concentrations, i.e. clusters (Johansson & Karlsson, 2001). It is important to observe that scale economies imply a location advantage for large functional regions with regard to all kinds of products with a "thin" demand. Hence, large urban regions can specialise in diversity and rely on the double force of internal and external scale economies and develop a number of different, often interacting, clusters. Of course, high land values in large regions with a high economic density are a counteracting force. Thus, firms in large functional regions must be more productive in order to be able to cover the extra costs for land and premises in such environments. But this is precisely where internal and external scale economies become important, since they offer the necessary cost savings.

However, scale economies constitute an equally important phenomenon for functional regions, which are small or medium-sized. For small and medium-sized regions specialisation can have two basic forms. The first may be thought of as the classical Ricardian case, in which a small or medium-sized region hosts industries, which are natural resource based and for which internal economies of scale are important. The second form of specialisation refers to the idea of localised external economies of scale discussed above. In this case small or medium-sized functional regions may also develop a specialisation, i.e. a cluster, in a self-organised way. In such a development one can observe the agglomeration of a narrow set of industries within the same sector, which are able to generate external economies of scale, i.e. localisation economies.

The cumulative process that in this case generates a cluster can be specified as follows: Firms in a core industry with localisation economies locate together in a functional region. This attracts input suppliers and labour categories, which are specialised with regard to the pertinent sector to the region. (Sometimes one can observe how industry-specific customers are attracted to the region). The environment of industry-specific input suppliers and employment categories as well as the core firms themselves form an economic milieu, i.e. a cluster, which attracts such industry-specific firms to locate and expand in the region.

One major implication of the above discussion is that one should expect clusters to emerge not only in large but also in medium-sized and small functional regions. Hence, we should look for clusters in regions of all sizes in our empirical exercises. Of course, clusters of different size can be expected to function in partly different ways but seen from a regional policy perspective it can obviously be motivated to stimulate cluster development in regions of all sizes.

Having established that clusters may develop in regions of all sizes the next question concerns what happens with the number of clusters over time. What happens with the number of clusters is of course influenced by what happens with the size of the sector. Does it grow, stay constant or decline? It is also influenced by the technological changes over time within the sector, since technological changes may change the balance between the centripetal and centrifugal forces affecting the sector. Taking the ICT sector as an example one may for example think that an increased used of the Internet will lead to a substantial reduction of transport costs and other geographical transaction costs. This would lead to a significant decrease in the centrifugal forces. Thus, other things equal there should be an increasing spatial agglomeration of ICT sector activities, and a decrease in the number of ICT clusters. This force may of course be balanced by a rapid growth of the ICT sector.

However, there is also an opposing view. As telecommunications infrastructures improve and the use of the Internet increases, people no longer have to be together in one physical place for certain collaborative face-to-face communications. This implies that intra-regional knowledge spillovers become less important, and so, other things equal, the centripetal forces decline, spatial agglomeration decreases and the number of ICT clusters increases.

We now turn to the life cycles of clusters. Historical examples clearly tell us that even very successful clusters may have a limited life span. What then determines the sustainability of clusters? It has been argued that the sustainability of an ICT cluster will derive from constant innovation, which in turn must be based on leading-edge research and researcher training (Greene, 2001). However, this conclusion seems too trivial, since it implies that ICT clusters would always develop around research universities. Empirical observations show that it is not always the case. Thus, we need a more general approach to the question what makes some clusters stick while others fall apart. The factors that allowed clusters to form may not necessarily be as important in sustaining them. Especially when many believe that randomness and historical accidents are integral components of how a cluster starts to develop (de Vol, 2001). Such a general theory of cluster sustainability should not only be applicable to high-tech clusters but to all sorts of clusters. If such a general theory cannot be developed then we have to search for theories of sustainability for different basic types of clusters.

According to some authors the risks to cluster sustainability consist of structural rigidities and cyclical disturbances (Bergman, 2002; Fritz, Mahringer & Valderrama, 1999; Tichy, 1998). We argue that there may also exist (at least) two additional types of risks. The first one has the form of fundamental technological change, either in the form of a totally new product satisfying a given need or in the form a new type of large-scale production technology making it impossible for producers using older production technologies to compete. The second type of risk we may call the cluster competition effect. It can be found in larger regions hosting several clusters and functions in such a way that a new, expanding, profitable cluster out-competes one or several existing clusters in the markets for land, premises, and labour by raising the price level in these markets. Obviously, we can make a distinction between internal threats (structural rigidities) and external threats (cyclical disturbances, fundamental technological changes and cluster competition effects) to cluster sustainability.

Tichy (1998) argues that cluster sustainability is a matter most properly considered over a fairly long development wave, during which it first forms, then grows rapidly and eventually reaches maturity or decay. He models the process as an analogue to the product life cycle theory. What must remembered, however, is that this cluster life cycle process might be brought to a rapid end by cyclical disturbances in particular. Fundamental technological changes normally threatens existing cluster in the medium term since firms using the older technology has a sunk-cost advantage vis-à-vis a new technology. Cluster competition effects normally also makes themselves felt in the medium-term since new clusters have to grow for quite some time before they become large enough to influence the price level in a region. We may here imagine a substitution process where in successful regions older clusters give way for new expanding clusters over time.

The internal threats – the structural rigidities – are different in the sense that they can develop gradually within a cluster starting already during the growth phase. However, the structural rigidities are unlikely to bring a cluster to a rapid death. Instead they are likely to become stronger over time making the cluster less and less able to react to changes in market demand and to develop new product varieties or to the emergence on the market of new product and process technologies. The structural rigidities may emerge within the cluster firms but they may also develop in the economic milieu surrounding the cluster in the form of obsolete infrastructure, obsolete labour training and education, obsolete R&D, obsolete institutions, and so on. In a more evolutionary framework (Nelson & Winter, 1982) one could also imagine clusters specialising in what in the selection process turns out to be inferior or less preferred technologies.

Given this discussion we have every reason to expect over time the decline but also the disappearance of certain clusters even in periods when the sector in question expands rapidly.

3. An empirical method to identify industrial clusters

In this section we present a straightforward method that facilitates the identification of industrial clusters. Or put differently, we suggest a method, which distinguishes regions that exhibit the necessary conditions to qualify as a cluster.[2] (The methodology is subsequently applied to Swedish ICT-data in Section 4 below.) Our basic starting point is the idea that in order for any industrial sector to qualify as a cluster in any given functional region, the sector must be over-represented in terms of both the number of employees and the number of firms. If a region exhibits over-representation only in employment, this suggests large-scale production but low levels of entrepreneurship. Such a region will not demonstrate a sufficient diversity in the actual sector to qualify as a cluster. On the other hand, a region with over-representation in only the number of firms demonstrates high entrepreneurship, but suggests small-scale production. Such a region lacks a sufficiently large qualified and diversified labour pool to generate the informational spillovers characterised by a cluster. Therefore, we argue that an over-representation in relation to the regional size in both the number of firms and employment defines a necessary (minimum) condition for the existence of a cluster.

The number of employees and the number of firms are generally highly correlated with the population, or size, of a region. However, some regions deviate from this general pattern, both in a positive as well as in a negative direction. By stating that the positive deviance should be higher than a certain percentage for both employment and the number of firms we are able to identify which regions that contain a cluster.[3]

When applying this method we have estimated the following two regression equations:

$$\ln Emp_r^i = a_1 + b_1 \ln Pop_r + \varepsilon_1 \qquad (3.1)$$

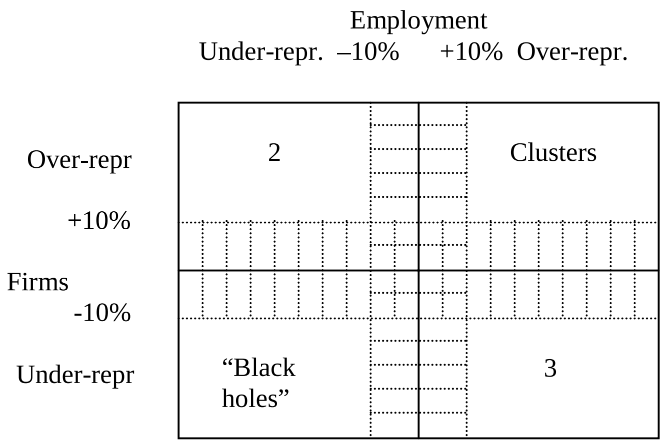
$$\ln Pla_r^i = a_2 + b_2 \ln Pop_r + \varepsilon_2 \qquad (3.2)$$

where Emp_r^i is employment in sector i in region r, Pla_r^i is number of plants[4] in sector i in region r, Pop_r is population in region r, ln is the natural logarithm and ε is the error term, which is assumed to be normally distributed. The residuals are saved and we say that for those cases where the residual is positive and above 10 percent for both employment and plants for any given sector, then a regional cluster is identified.

Since the methodology proposed not only enables us to identify already existing clusters but also provides an analysis of regions with a weaker sectoral development, we can classify regions by their respective representation in both employment and number of firms for any given sector. An interesting implication of this classification is that it generates insights into what would constitute efficient policy measures for any region that want to develop a given sector into a cluster. Figure 3.1 below illustrates this.

[2] From here on we will use the term cluster for any region that satisfies the necessary condition (or minimum criteria).
[3] The magnitude of deviation chosen as cut-off value, i.e. the percentage, is arbitrary. The higher value of deviation needed to qualify as a cluster, the less clusters can be identified.
[4] Plants are individual production units. They often are but need not a legal entity, i.e. a firm.

Figure 3.1 Classification of regions with respect to over- and under-representation of number of firms and level of employment.



The method outlined above enables us to map every region within Figure 3.1. In the northeast quadrant we can find the regions with an identified cluster. Having established what regions fulfil the conditions for containing a cluster it is then possible in a second step to study those clusters in more detail using, for example, input-output analysis, graph analysis, correspondence analysis, social network analysis, or a qualitative case study approach of the Porter type (Roelandt & den Hertog, 1999). Thus, we believe that regional cluster analyses should be conducted as a two-stage process.

In the southwest quadrant in Figure 3.1 we find the “black holes”, i.e. regions that are significantly under-represented in the number of firms as well as in the level of sectoral employment. Such regions would most likely do better finding growth opportunities in other sectors. While it is not impossible to transform a “black hole” into a cluster (using policy), our conjecture is that such endeavours are high risk at a high cost. In the box labelled 2 we find regions with an over-representation in the number of firms but an under-representation in employment. Parallel to this is box 3, where we find regions with an over-representation in employment but with an under-representation in the number of firms. It is in these two boxes we are most likely to find potential candidates for future clusters. However, the required policy to generate this transformation differs significantly between the two boxes. Regions mapped in box 2 should concentrate on policy aimed at increasing the level of employment in existing firms, i.e. efficient policy should be aimed at stimulating growth of already existing firms (providing they are, or have a reasonable potential of becoming, profitable). On the other hand, regions mapped in box 3 will do best if concentrating policy measures on stimulating new firm creation, where new firms could benefit from the large existing labour pool. Furthermore, the “lined” area in Figure 3.1 identifies regions, which would be particularly sensitive to policy measures. Such areas have a higher probability to benefit from policy compared to regions mapped in the outer northwest, southwest, and southeast corners of the figure.

By keeping track over how the different regions “move” in the diagram over time it is also possible to identify emerging clusters as well as clusters that are declining. Hence, the diagram could provide policy makers at the regional level with policy relevant information. With emerging clusters identified the policy makers are able to decide which of these emerging clusters should be supported. As regards declining clusters the policy makers probably have a tougher choice, since there might be a strong political, union and public pressure to support declining clusters even if their future is not bright. Anyhow, the method helps to identify what clusters are declining.

This method relates the concept of a cluster to the relative size of a region. However, one could oppose to this approach by arguing that there are an absolute size needed in order to qualify as a cluster. That is, clusters need a critical mass, which suggests that larger regions could have clusters even though they are relatively under-represented in terms of both number of firms and employment. While this could be true, we are not inclined to favour such a viewpoint, since it implies granting the label “cluster” to a sector in a region that under-performs in a national comparison. However, we differentiate between macro, meso, and micro clusters in order to distinguish between the absolute sizes of identified clusters.

In many cases location quotients have been used to identify industrial clusters. However, there are many potential conceptual and measurement pitfalls in using location quotients (Isard, et al., 1998). For example, the maximum value of the location quotient depends on the size of regions. This problem is avoided with the method suggested in this paper. Furthermore, most studies using location quotients concentrate on employment only. We consider an over representation in terms of plants as a criteria at least as important as employment over representation.

4. ICT clusters in functional regions in Sweden

In this section we apply the method outlined above to identify industrial clusters in functional regions in Sweden using data for the ICT sector. The functional regions used are so called local labour market regions. These regions normally, except in sparsely populated areas, consist of several municipalities and are identified and defined by commuting data. According to NUTEK (?) there exists 81 local labour market regions in Sweden. The data used for the ICT sector are collected by Statistics Sweden. The database contains data at the municipal level concerning number of employees, number of plants, size distribution of plants, and the educational level of the employees for about 750 different industries.

In total the Swedish ICT sector employed almost 355,000 people in the year 2000. Between 1990 and 2000 the number of employees increased by almost 34 percent, while total employment in Sweden decreased during the same period. The number of ICT plats was in the year 2000 a little more than 38,700. The number of ICT plants increased during the period 1990-2000 with a speed that was almost double that of ICT employment or just over 57 percent.

Table 4.1 presents the estimations of Equation (3.1) for 1990 and 2000. As expected, we can see that the size of the regional population provides a good explanation for the magnitude of ICT sector employment at the regional level, but that the explanatory power has declined somewhat between 1990 and 2000. The regression line has shifted upwards significantly between 1990 and 2000, indicating an overall increase in ICT sector employment during the period. The population elasticity has declined between 1990 and 2000, indicating that ICT sector employment in relative terms has increased more in smaller than in larger regions.

Table 4.1 The relationship between employment in the ICT sector and the population in functional regions in 1990 and 2000.

	1990	2000
Constant (t-value)	-7.80 (15.2)	-6.27 (10.4)
ln population (t-value)	1.32 (27.9)	1.21 (21.7)
R^2-adj.	0.91	0.86
No of observations	81	81

The relationship between the number of plants in the ICT sector and the population in functional regions for 1990 and 2000 is illustrated in Table 4.2. We see that regional population explains the variation in the number of plants in the ICT sector between different regions relatively well. The regression line has a higher position in 2000 than in 1990 indicating a general expansion of number of ICT plants during the period. The population elasticity has decreased slightly during the period and is lower than for employment in the ICT sector (See Table 4.1). This suggests that there now exist relatively better opportunities to benefit from advantages of scale economies in larger regions.

Table 4.2 The relationship between the number of plants in the ICT sector and the population in functional regions in 1990 and 2000.

	1990	2000
Constant (t-value)	-8.14 (-33.8)	-7.21 (-28.2)
ln population (t-value)	1.16 (52.2)	1.12 (47.1)
R^2-adj.	0.97	0.97
No of observations	81	81

In the next step we study the residuals from the four regressions. For those local labour market regions where the positive residual is larger than 10 percent for both employment and the number of plants we claim that a minimum requirement for the existence of an ICT cluster is fulfilled. The regions with an ICT cluster in 1990 and/or 2000 are presented in Table 4.3. In 1990 there were 13 regions with an ICT cluster in Sweden. Ten years later the number of regions with an ICT cluster had increased to 19 illustrating the general expansion of the ICT sector in Sweden during this period. However, four regions that had an ICT cluster in 1990 were out of the game in 2000. As the number of ICT clusters in Sweden has increased during the period 1990-2000 this can be taken as an indication that the centrifugal forces have dominated over the centripetal forces within the ICT sector in Sweden.

In Table 4.3 we make a distinction between macro, meso and micro clusters based upon the size of the clusters.[5] In 1990 there was one macro cluster, six meso clusters and six micro

[5] Clusters are defined as macro if there are above 10,000 individuals employed within the sector regionally, as meso if employment is between 1,000 and 10,000, and subsequently as micro if employment is below 1,000 individuals. Of course, this classification is arbitrary and any division into macro, meso, and micro is a matter of judgement.

clusters in the ICT sector in Sweden. 10 years later there was three macro clusters, eight meso clusters and eight micro clusters. Of the 19 clusters in 2000 ten of them including the eight were located in regions in the sparsely populated northern part of Sweden. This fact can be interpreted in different ways. One possible interpretation is that the new ICT technology has such characteristics that ICT goods and services can be developed or at least produced at long distance from the large markets. Another possible interpretation is that distance still matters and that to de supplied at all in the sparsely populated regions the ICT services must be supplied locally.

Table 4.3 Local labour market regions in Sweden with an ICT cluster in 1990 and or 2000.[6]

	ICT cluster 2000	
ICT cluster 1990	Yes	No
Yes	Stockholm* Västerås** Karlstad** Sundsvall** Jönköping** Ljusdal*** Storuman*** Överkalix*** Sorsele***	Umeå** Söderhamn** Åmål*** Malung***
No	Gothenburg* Malmö* Uppsala** Växjö** Östersund** Skellefteå** Härjedalen*** Vilhelmina*** Arvidsjaur*** Arjeplog***	

Detailed information about the individual stable, incoming and disappearing clusters can be found in Appendix B. In Table 4.4 and Table 4.5 we present some aggregated information about the development of these different groups of clusters as well as for the rest of the Swedish economy. Comparing the figures in Table 4.4 and Table 4.5 we see that the aggregated picture for the stable ICT clusters is that the number of plants has increased with a speed that is more than double that of the employment, indicating a high level of entrepreneurship. The incoming clusters are characterised by that employment has increased somewhat more rapid than the number of plants. For the disappearing clusters we see that the aggregated picture is that of a substantial employment loss, at the same time as the increase in the number of plants is the lowest for any category in Table 4.5. For the rest of Sweden we can observe that the number of plants has increased with a speed that is double that of the employment increase.

[6] * = macro cluster, ** = meso cluster, *** = micro cluster

Table 4.4 Employment 1990 and 2000 and employment change 1990-2000 in stable, incoming, and disappearing ICT clusters in Sweden

Aggregate	**1990**	**2000**	**1990-2000 (%)**
Stable clusters	134,490	179,643	+33.6
Incoming clusters	54,239	81,171	+49.7
Disappearing clusters	5,317	3,824	-28.1
The rest of Sweden	70,957	90,087	+27.0
The whole of Sweden	**265,003**	**354,725**	**+33.9**

Table 4.5 Number of plants 1990 and 2000 and change in number of plants 1990-2000 in stable, incoming, and disappearing ICT clusters in Sweden

Aggregate	**1990**	**2000**	**1990-2000 (%)**
Stable clusters	11,163	18,795	+68.4
Incoming clusters	6,112	8,680	+42.0
Disappearing clusters	421	575	+36.6
The rest of Sweden	6,935	10,677	+54.0
The whole of Sweden	**24,631**	**38,727**	**+57.2**

In Sweden there are in total 81 labour market regions. In Appendix C we have characterised all these regions with respect to the representation of ICT employment and ICT plants as indicated by the residuals from estimating Equations (3.1) and (3.2). The table in Appendix C is interesting since it has strong policy implications. It illustrates which regions that possibly could develop an ICT cluster in the near future as well as regions that should search other avenues for their development rather than trying to develop the ICT sector through policy ("the black holes"). Put differently, the table identifies the regions, which are most likely to benefit from and be most sensitive to policy measures in order to develop their respective ICT-sector into a cluster. However, it also indicates what type of policies that should be pursued in different regions if they would like to try to develop an ICT cluster. In regions with a strong ICT entrepreneurship it is important to support growth in existing enterprises. On the other hand in regions with a high employment is it instead important to stimulate entrepreneurship. "Average regions" might follow a balanced strategy. If we study where the regions that qualify as clusters in 2000 but not in 1990 did come from we see that one did come from cell 1, four from cell 2, two from cell 4, two from cell 6 and one from cell 7. This illustrates that it is very difficult but not totally impossible for regions that are a "black hole" to develop a cluster even in periods when the actual sector grew very rapidly. Of the disappearing clusters one went to cell 1, one to cell 4 and two to cell 5.

To further characterise the clusters we also study their degree of diversification, i.e. if they contain more industries than expected given the size of the actual region. Since the number of industries in regions increases with the size of regions but at a decreasing rate we use the following equation for the estimations:

$$\ln Ind_r^i = \alpha_3 + \beta_3 \ln Bef_r + \gamma_3 (\ln Bef_r)^2 + \varepsilon_3 \quad (4.1)$$

where Ind_r^i is the number of industries in sector i in region r. We save the residuals from the estimations and demand that the residual should be 10 percent higher than the expected value for a cluster to be considered as diversified. The results from estimating Equation (4.1) can be found in Table 4.6. We see from the constant that the curve has shifted upward substantially between 1990 and 2000 indicating a general increase of the number of ICT-industries in the functional regions in Sweden, i.e. a diffusion of ICT industries. Furthermore, we can observe that the population elasticity has decreased substantially indicating that in particular smaller regions have gained in this diffusion process. In Appendix B we can see that all cluster regions in both 1990 and 2000 were diversified clusters in the sense that they contained more industries than could be expected given the size of the cluster regions.

Table 4.6 The relationship between the number of industries in the ICT sector and the population in functional regions in the years 1990 and 2000.

	1990	2000
Constant (t-value)	-10.75 (-10.4)	-6.23 (-7.6)
ln population (t-value)	2.12 (11.1)	1.38 (9.1)
(ln population)^2 (t-value)	-7.66E-02 (-8.7)	-4.65E-02 (-6.6)
R^2-adj.	0.93	0.92
No of observations	81	81

ICT clusters can also be characterised according to their knowledge intensity. To do that, we estimate the relationship between the number of employees with a long university education (three years or more) in the ICT sector and the size of the functional region in accordance with Equation (4.2).

$$\ln Uni_r = a_1 + b_1 \ln Pop_r + \varepsilon_1 \quad (4.2)$$

where Uni_r is the number of employees with a long university education in the ICT sector in region r. Once again we examine the residuals and apply the criteria that the residual for the employment of university-trained employees must be significantly larger than the residual for the total number of employees according to Equation (3.1). The results from estimating Equation (4.2) can be found in Table 4.7. The results reported in the table show that that there has been a general increase in the number of people with a long university education employed in the ICT sector in the functional regions in Sweden. However, the population elasticity has only decreased slightly between 1990 and 2000 indicating that there have not been any major changes in the distribution of highly educated labour in the ICT sector, i.e. that the differences in the knowledge intensity in the ICT sector between large and small regions have been constant between 1990 and 2000. The education elasticity is also substantially higher than the employment elasticity (See Table 4.1.), which means that the ICT sector on average is much more knowledge intensive in large functional regions than in small functional regions.

Table 4.7 The relationship between the number of employees with a long university education in the ICT sector and the population in functional regions in the years 1990 and 2000.

	1990	2000
Constant (t-value)	-14.15 (-17.2)	-12.71 (-18.5)
ln population (t-value)	1.65 (21.9)	1.59 (25.0)
R^2-adj.	0.86	0.89
No of observations	81	81

In Appendix B we see that the clusters vary to what extent that their use of university-trained employees is significantly larger in relative terms then their general employment. Not all ICT clusters could be characterised as knowledge-intensive in 1990 and 2000, respectively.

5. Conclusions and suggestions for future research

In this paper we propose an empirical method to identify the existence of spatial clusters. The method, based upon regression analysis, offers researchers to categorise regions, municipalities, or cities with respect to their over- or under-representation in the number of establishments and employment for any arbitrary industry. It is suggested that a necessary condition for the existence of a cluster entails a significant overrepresentation in both the number of establishments as well as in employment for any given sector in a region. Furthermore, this over-representation should be related to the size of the region. The categorisation generated by the proposed method also has policy implications for any region aiming at developing and supporting a potential or emerging cluster. The present paper offers an analysis of the ICT-sector in Sweden, where the proposed method is used to identify potential clusters in the 81 Swedish functional regions. Furthermore, a comparison in time between 1990 and 2000 is also offered.

The criteria proposed in this paper to identify industrial clusters determine the necessary and sufficient conditions for the existence of a cluster. However, we are not able to tell whether the identified clusters are pure agglomerations, industrial complexes or industrial networks along the lines suggested by Gordon & McCann (2000). To do that it is necessary to study the identified clusters empirically. This should be a fruitful avenue for future research. The necessary starting point for such research must be the identification of the necessary and sufficient conditions for the existence of industrial complexes and industrial networks, respectively. Besides trying to categorise the identified industrial clusters in the ICT sector it would of course be worthwhile to test the proposed method on other industrial sectors. It would also be necessary to test whether one should use another explanatory variable but regional population. One could for example imagine that accessibility to population or to income at least sometimes could be a better explanatory variable.

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Appendix A Definition of the ICT-sector including a division into sub-sectors

Branch NACE Rev. 1[7]	**Description**
Hardware/Manufacturing	
3010	Manufacture of office machinery
3020	Manufacture of computers and other information processing equipment
3130	Manufacture of insulated wire and cable
3210	Manufacture of electronic valves and tubes and other electronic components
3220	Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy
3230	Manufacture of television and radio receivers, sound or video recording or reproducing apparatus and associated goods
3320	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment
3330	Manufacture of industrial process control equipment
7250	Maintenance and repair of office, accounting and computing machinery
Telecommunications	
6420	Telecommunications
Software	
7210	Hardware consultancy
7220	Software consultancy and supply
7230	Data processing
7240	Data base activities
7260	Other computer related activities
Content	
2210	Publishing
7440	Advertising
9210	Motion picture and video activities
9220	Radio and television activities
9240	News agency activities
Other services (Wholesale etc)	
5143	Wholesale of electrical household appliances and radio and television goods
5165	Wholesale of other machinery for use in industry, trade and navigation
52493	Retail sale of computers, office machinery and computer programmes
52494	Retail sale of telecommunication equipment
7133	Renting of office machinery and equipment including computers
7414	Business and management consultancy activities
Research	
73101	Research and development on natural sciences
73102	Research and development on engineering and technology
73201	Research and development on social sciences

[7] NACE is equivalent to the Swedish system (SNI92) at the four-digit level.

Appendix B A Characterisation of ICT clusters in Sweden

Region	Type of ICT cluster	ICT Employment		Employ-ment change (%)	Number of ICT plants		Change in the number of plants (%)	Diversified cluster		Knowledge intensive cluster	
		1990	2000		1990	2000		1990	2000	1990	2000
Stockholm	Stable macro	114,775	156,600	36	9,622	16.384	70	Yes	Yes	Yes	No
Jönköping	Stable meso	3,808	4,666	23	329	533	62	Yes	Yes	No	Yes
Karlstad	Stable meso	3,908	4,397	13	381	594	56	Yes	Yes	Yes	Yes
Västerås	Stable meso	6,837	8,214	20	386	652	69	Yes	Yes	No	Yes
Sundsvall	Stable meso	4,606	4,690	2	375	531	42	Yes	Yes	No	Yes
Ljusdal	Stable micro	320	631	97	38	55	45	Yes	Yes	No	Yes
Storuman	Stable micro	171	146	-15	20	23	15	Yes	Yes	Yes	Yes
Sorsele	Stable micro	25	194	676	5	11	120	Yes	Yes	Yes	Yes
Överkalix	Stable micro	40	105	163	7	12	71	Yes	Yes	Yes	Yes
Göteborg	Incoming macro	27,945	39,112	40	2,916	4,488	54	-	Yes	-	Yes
Malmö	Incoming macro	16,463	24,260	47	1,934	2,934	52	-	Yes	-	Yes
Uppsala	Incoming meso	3,677	8,416	129	597	1,193	100	-	Yes	-	No
Växjö	Incoming meso	2,197	3,337	52	298	485	63	-	Yes	-	No
Östersund	Incoming meso	2,225	3,149	42	161	305	89	-	Yes	-	Yes
Skellefteå	Incoming meso	1,471	2,024	38	147	244	66	-	Yes	-	No
Härjedalen	Incoming micro	97	447	361	22	33	50	-	Yes	-	No
Vilhelmina	Incoming micro	93	234	152	20	40	100	-	Yes	-	No
Arvidsjaur	Incoming micro	59	116	97	13	20	54	-	Yes	-	No
Arjeplog	Incoming micro	12	76	533	4	12	200	-	Yes	-	No
Umeå	Disappearing meso	2,679	2,876	7	280	411	47	Yes	-	Yes	-
Söderhamn	Disappearing meso	1,530	389	-75	59	66	12	Yes	-	Yes	-
Åmål	Disappearing micro	863	483	-44	61	66	8	Yes	-	Yes	-
Malung	Disappearing micro	245	76	-69	21	32	52	Yes	-	No	-
The rest of Sweden		70,957	90,087	27	6,935	10,677	54				

Appendix C The 81 functional regions in Sweden characterised according to the representation of ICT employment and ICT plants as indicated by the residuals from estimating Equations (3.1) and (3.2).

	Employment residual –10 percent or lower	**Employment residual between +10 and –10 percent**	**Employment residual +10 percent and higher**
Plant residual +10 percent or higher	*1) Entrepreneurship without employment:* Helsingborg Vansbro Malung Mora Åre Övertorneå (6 regions)	*2) Entrepreneurship with average employment:* Falun Lycksele (2 regions)	*3) Clusters:* Stockholm Uppsala Jönköping Växjö Malmö Göteborg Karlstad Västerås Ljusdal Sundsvall Härjedalen Östersund Storuman Sorsele Vilhelmina Skelleftå Arvidsjaur Arjeplog Överkalix (19 regions)
Plant residual between +10 and -10 percent	*4) Low employment with average entrepreneurship:* Nyköping Hultsfred Västervik Simrishamn Halmstad Hagfors Söderhamn Örnsköldsvik (8 regions)	*5) Average regions:* Eskilstuna Gnosjö Karlshamn Åmål Arboga Umeå Kiruna (7 regions)	*6) Employment with average entrepreneurship:* Linköping Karlskrona Borås Årjäng Örebro Gävle Hudiksvall Strömsund Luleå Haparanda (10 regions)
Plant residual –10 percent or lower	*7) "Black holes":* Eksjö Tranås Oskarshamn Kristianstad Falkenberg Uddevalla Strömstad Lidköping Skövde Sunne Filipstad Arvika Fagersta Avesta Ludvika Bollnäs Sollefteå Jokkmokk Gällivare (19 regions)	*8) Low entrepreneur-ship with low employment:* Norrköping Kalmar Bengtsfors (3 regions)	*9) Large scale employment:* Katrineholm Älmhult Ljungby Gotland Karlskoga Kalix Pajala (7 regions)